



US007008858B2

(12) **United States Patent**
Liu et al.

(10) **Patent No.:** **US 7,008,858 B2**
(45) **Date of Patent:** **Mar. 7, 2006**

(54) **LIGHT EMITTING DIODE HAVING AN ADHESIVE LAYER AND A REFLECTIVE LAYER AND MANUFACTURING METHOD THEREOF**

6,416,194 B1 * 7/2002 Demiryont 359/883
6,597,019 B1 * 7/2003 Inoue et al. 257/99
2002/0053872 A1 5/2002 Yang et al.
2002/0105003 A1 * 8/2002 Yang et al. 257/94
2003/0168664 A1 * 9/2003 Hahn et al. 257/79

(75) Inventors: **Wen-Huang Liu**, Hsin-Chu (TW);
Tzu-Feng Tseng, Hsin-Chu (TW);
Min-Hsun Hsieh, Hsin-Chu (TW);
Ting-Wei Yeh, Hsin-Chu (TW);
Jen-Shui Wang, Hsin-Chu (TW)

OTHER PUBLICATIONS

(73) Assignee: **Epistar Corporation**, Hsinchu (TW)

Chen-Fu Chu et al., Fabrication and Characteristics of Freestanding GaN light emitting Devices by Laser Lift-off Technique, Proceedings of Opto-Electronics and Communications Conference. Jul. 8, 2002, No. 87. Yokohama, Japan.

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

F. S. Shieu et al., Effect of a TI Interlayer on the bond strength and thermal stability of the Cu/benzocyclobutene-divinyl tetramethyldisiloxane interface, J. Adhesion Sci. Technol., 1998, pp. 19-28, vol. 12, No. 1, VSP, Netherlands
R. H. Horng et al., AlGaInP light-emitting diodes with mirror substrates fabricated by wafer bonding. Applied Physics Letters, Nov. 15, 1999, pp. 3054-3056, vol. 75, No. 20, American Institute of Physics, USA.

(21) Appl. No.: **10/904,190**

(22) Filed: **Oct. 28, 2004**

(65) **Prior Publication Data**

US 2005/0077544 A1 Apr. 14, 2005

Related U.S. Application Data

(62) Division of application No. 10/604,245, filed on Jul. 4, 2003.

G. Dang et al., Comparison of Dry and Wet Etch Processes for Patterning SiO₂/TiO₂ Distributed Bragg Reflectors for Vertical-Cavity Surface-Emitting Lasers, Journal of The Electrochemical Society, 2001, G25-G28, vol., 148(2), The Electrochemical Society, Inc., NJ, USA.

(Continued)

(51) **Int. Cl.**

H01L 21/30 (2006.01)
H01L 21/46 (2006.01)
H01L 21/00 (2006.01)

Primary Examiner—Shouxiang Hu
(74) *Attorney, Agent, or Firm*—Winston Hsu

(52) **U.S. Cl.** **438/455**; 458/28; 458/459

(57) **ABSTRACT**

(58) **Field of Classification Search** 438/22, 438/24, 46-47, 28, 455, 458-459; 257/79-103
See application file for complete search history.

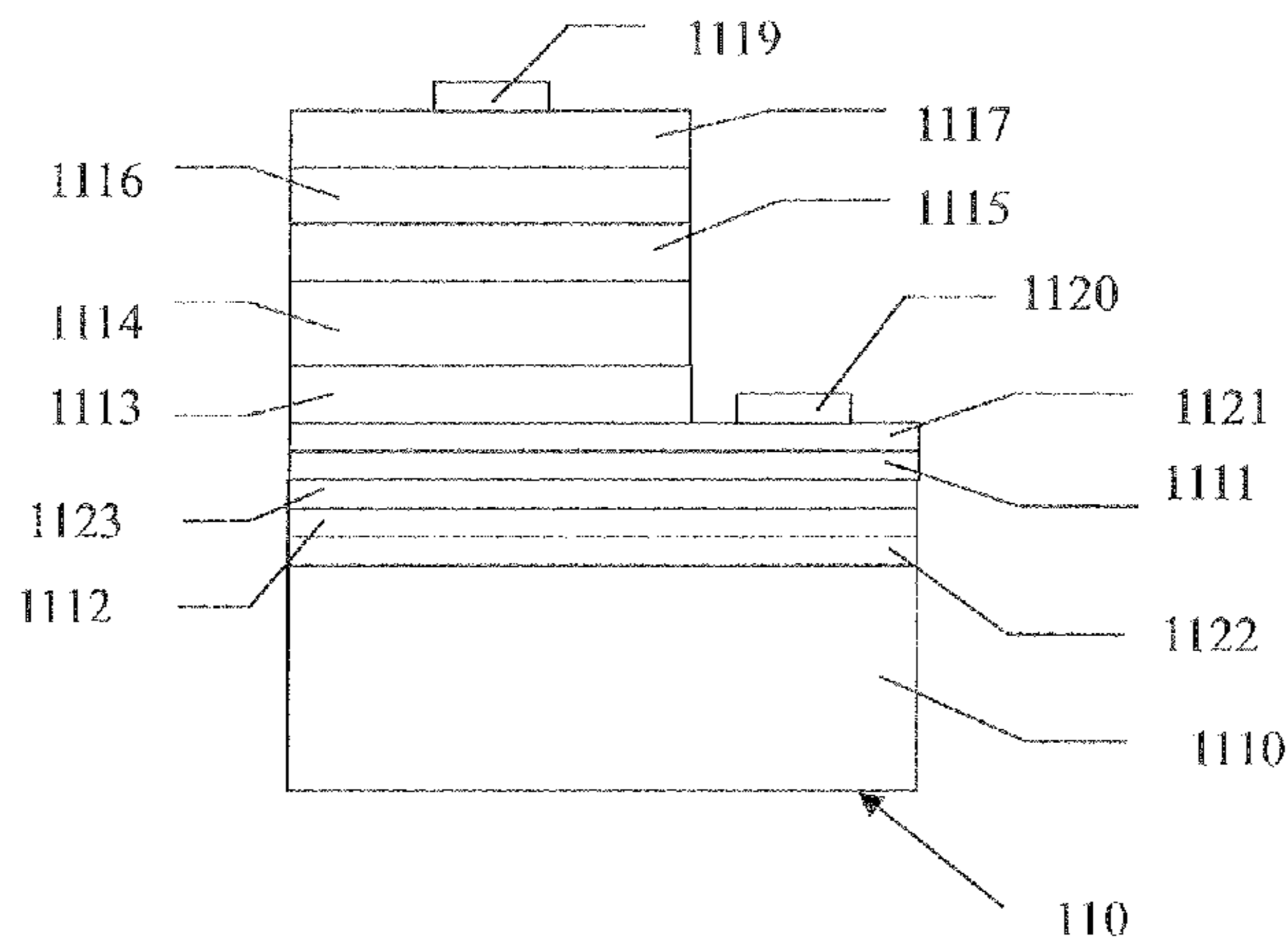
A light emitting diode having an adhesive layer and a reflective layer and a manufacturing method thereof featured by adhering together a light emitting diode stack and a substrate having a reflective metal layer by use of a transparent adhesive layer so that the light rays directed to the reflective metal layer can be reflected therefrom to improve the brightness of the light emitting diode.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,376,580 A 12/1994 Kish et al.
5,798,536 A * 8/1998 Tsutsui 257/99
6,287,882 B1 * 9/2001 Chang et al. 438/29
6,320,206 B1 * 11/2001 Coman et al. 257/94

6 Claims, 7 Drawing Sheets



OTHER PUBLICATIONS

T. Margalith et al., Indiumtin oxidecontacts to gallium nitride optoelectronic devices, *Applied Physics Letters*, Jun. 28, 1999, pp. 3930-3932, vol. 74, No. 26. American Institute of Physics, USA.

R. H. Horng et al., "AlGaN light-emitting diodes with mirror substrates fabricated by wafer bonding." *Appl. Phys. Lett.*, Nov. 15, 1999, pp. 3054-3056, vol. 75, No. 20.

* cited by examiner

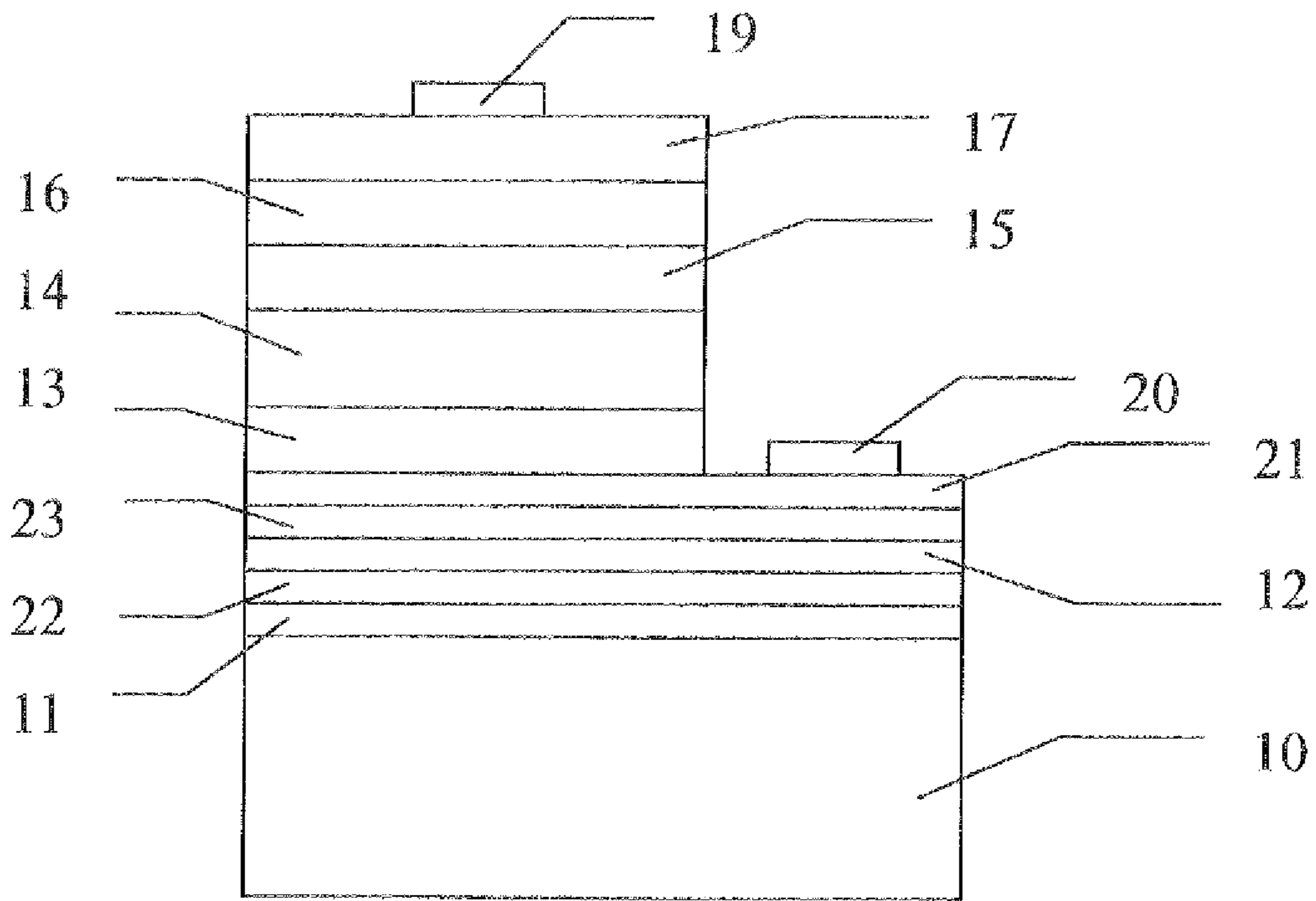


FIG. 1

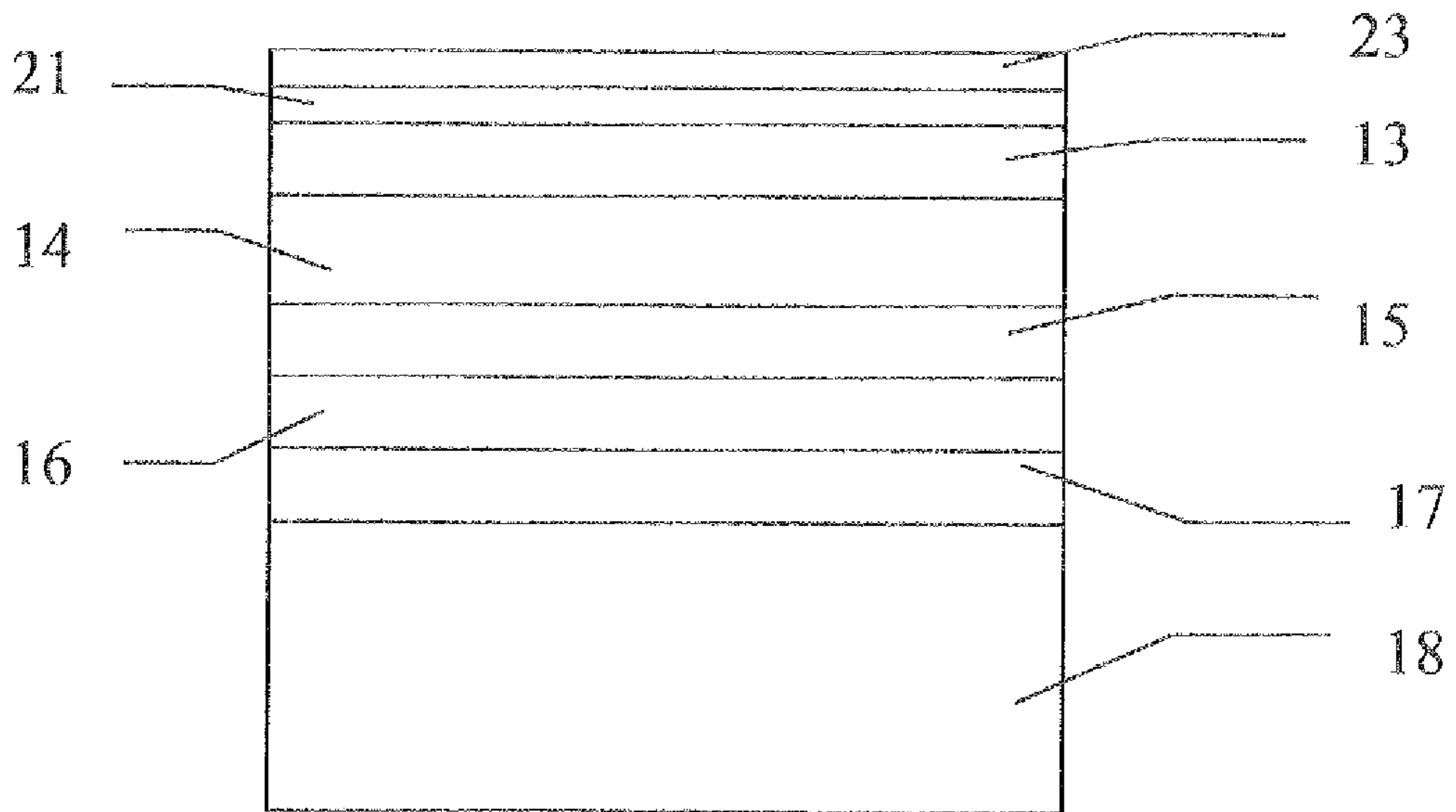


FIG. 2

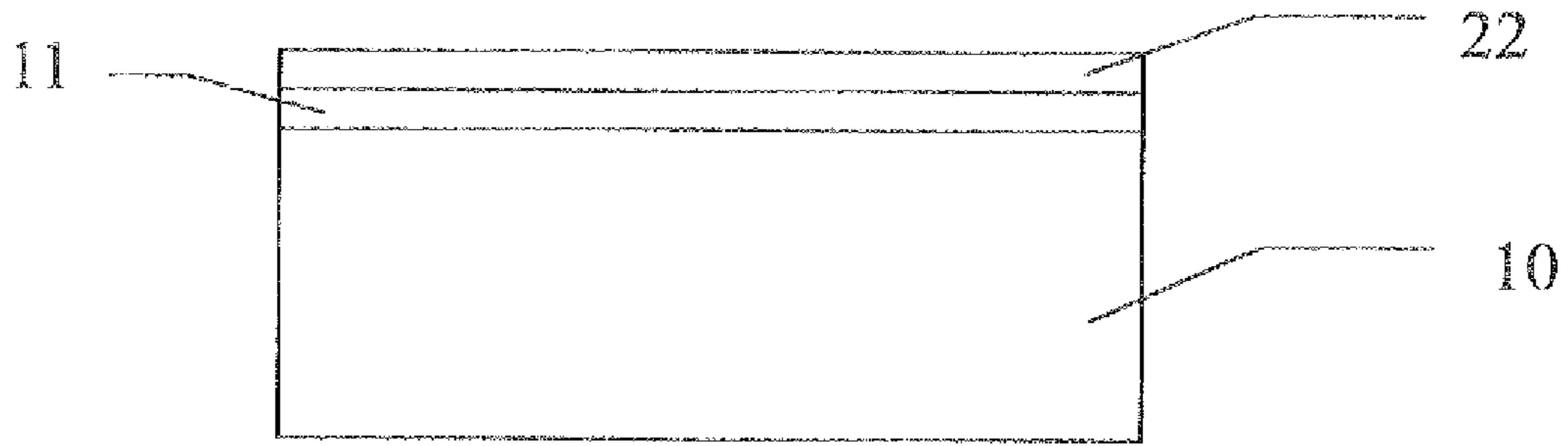


FIG. 3

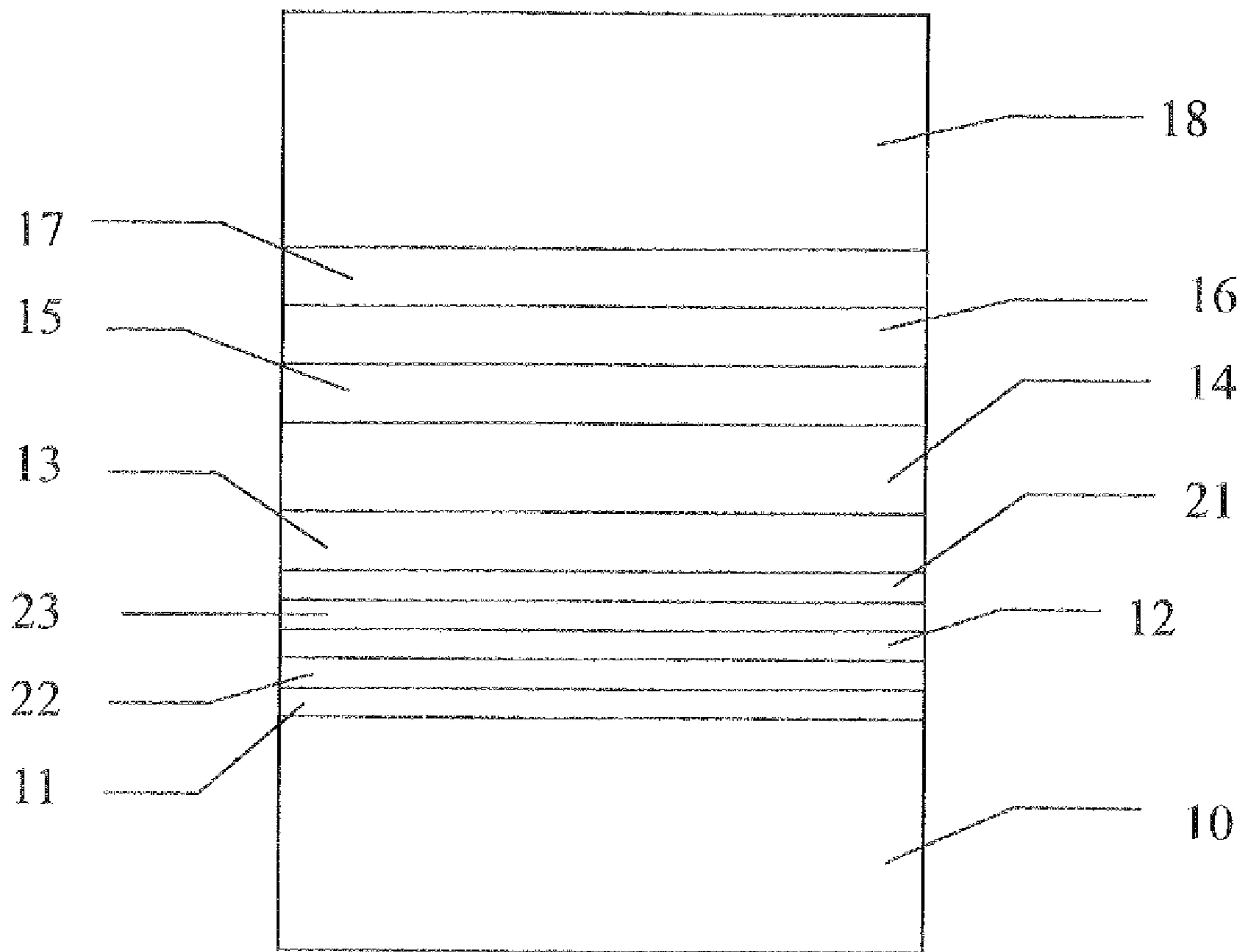
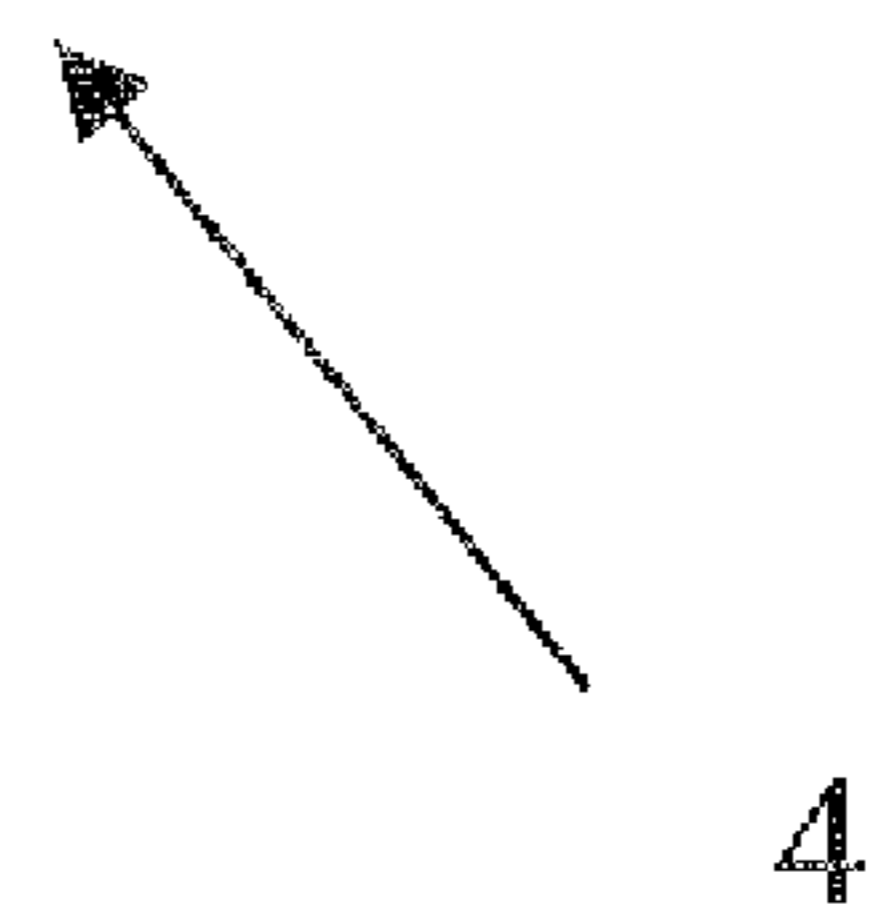


FIG. 4



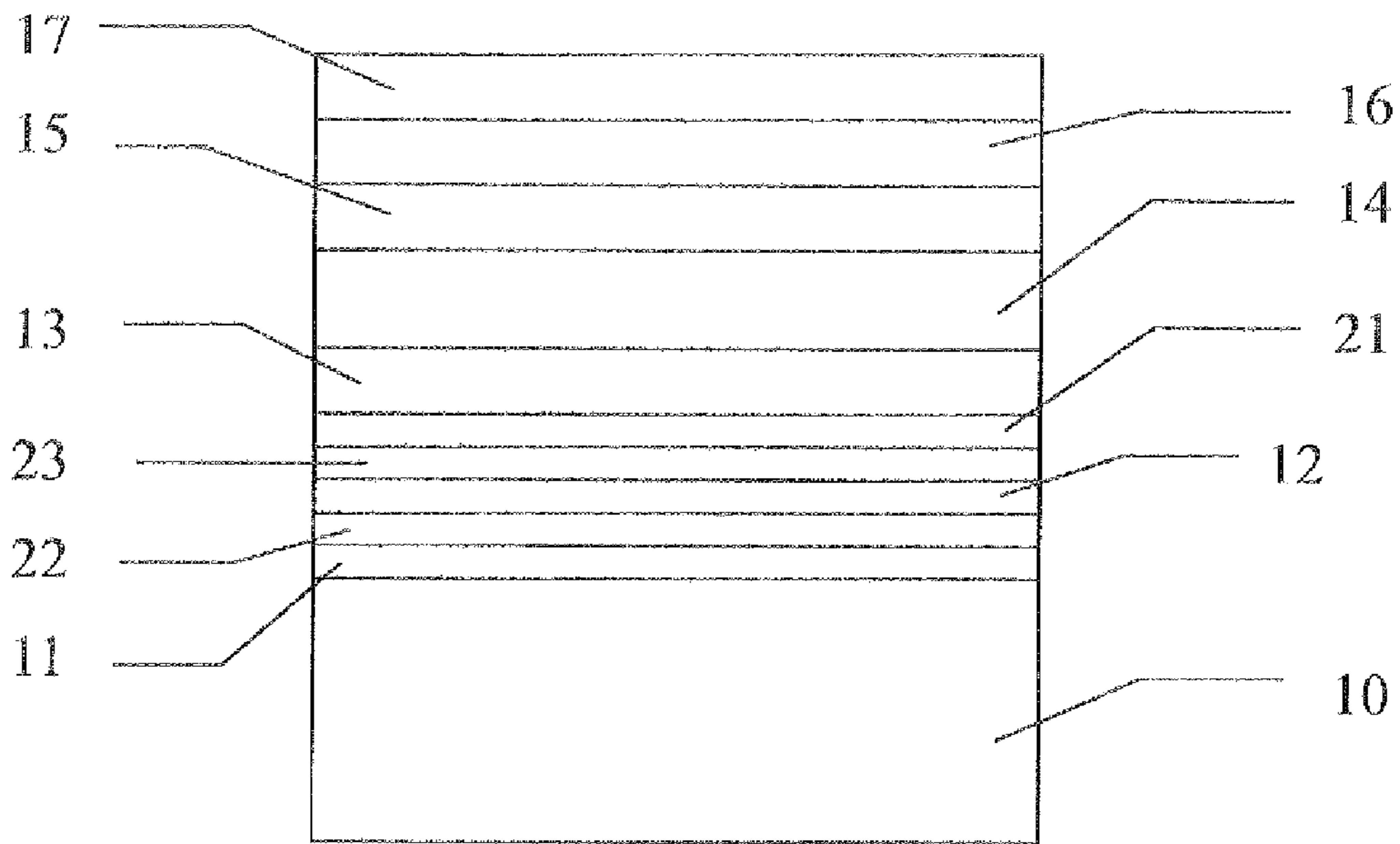
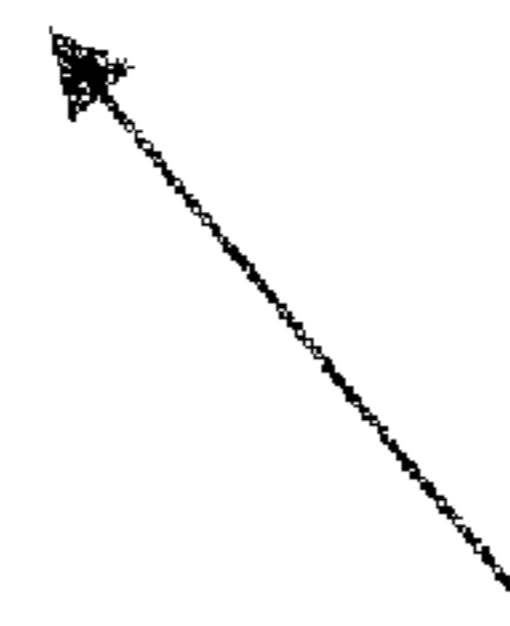


FIG. 5



5

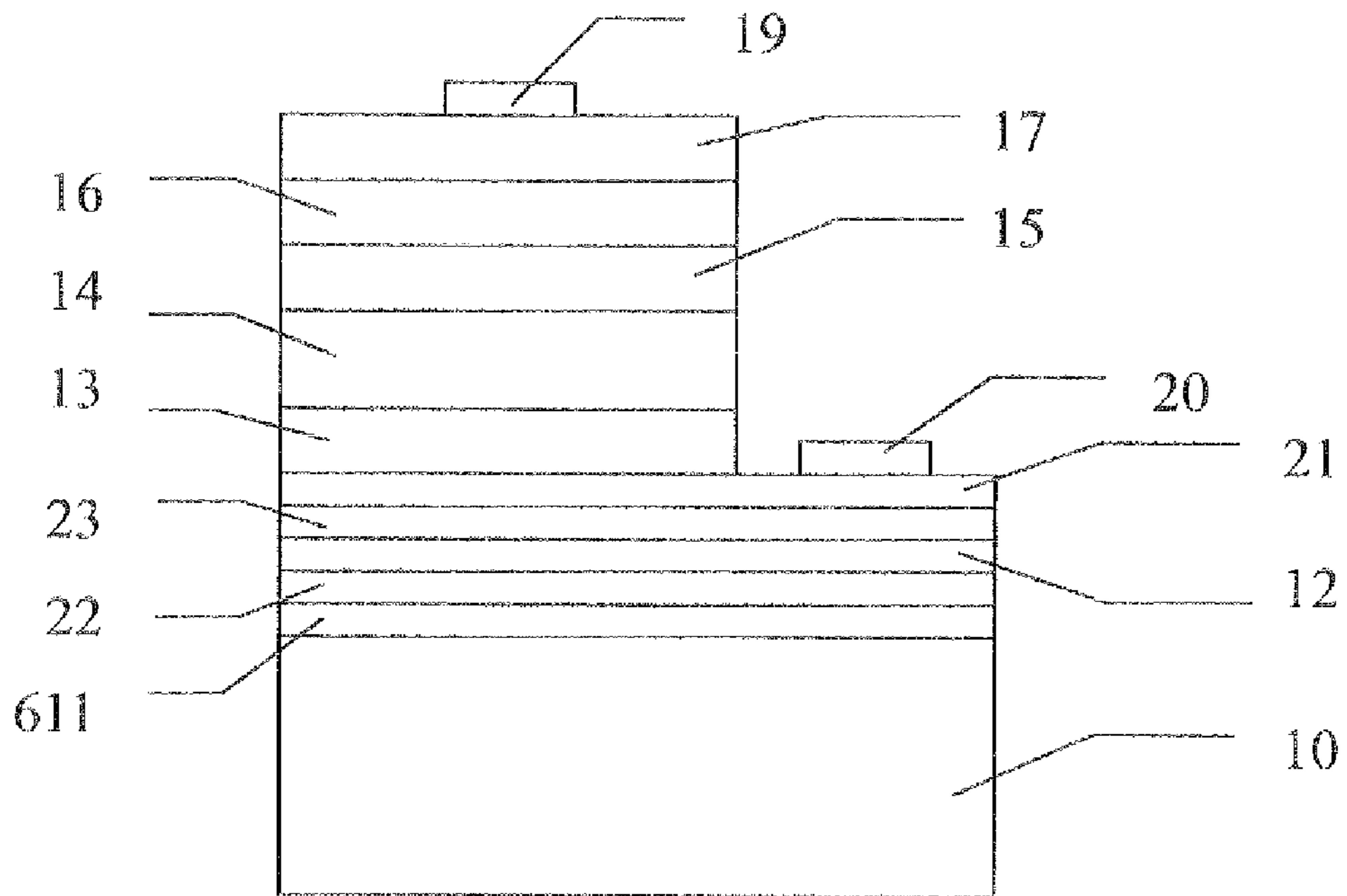
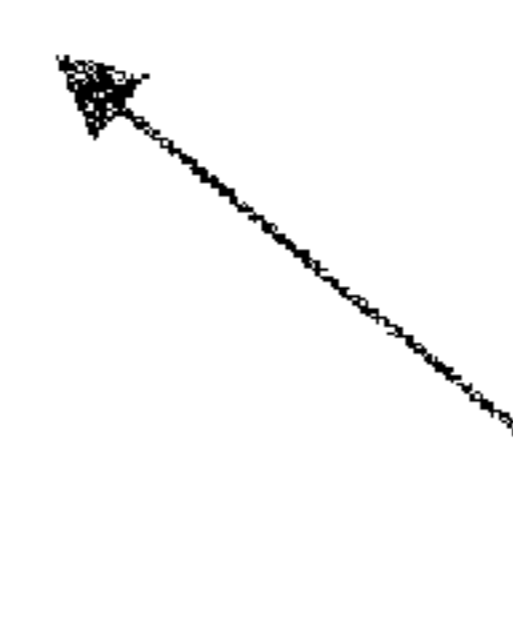
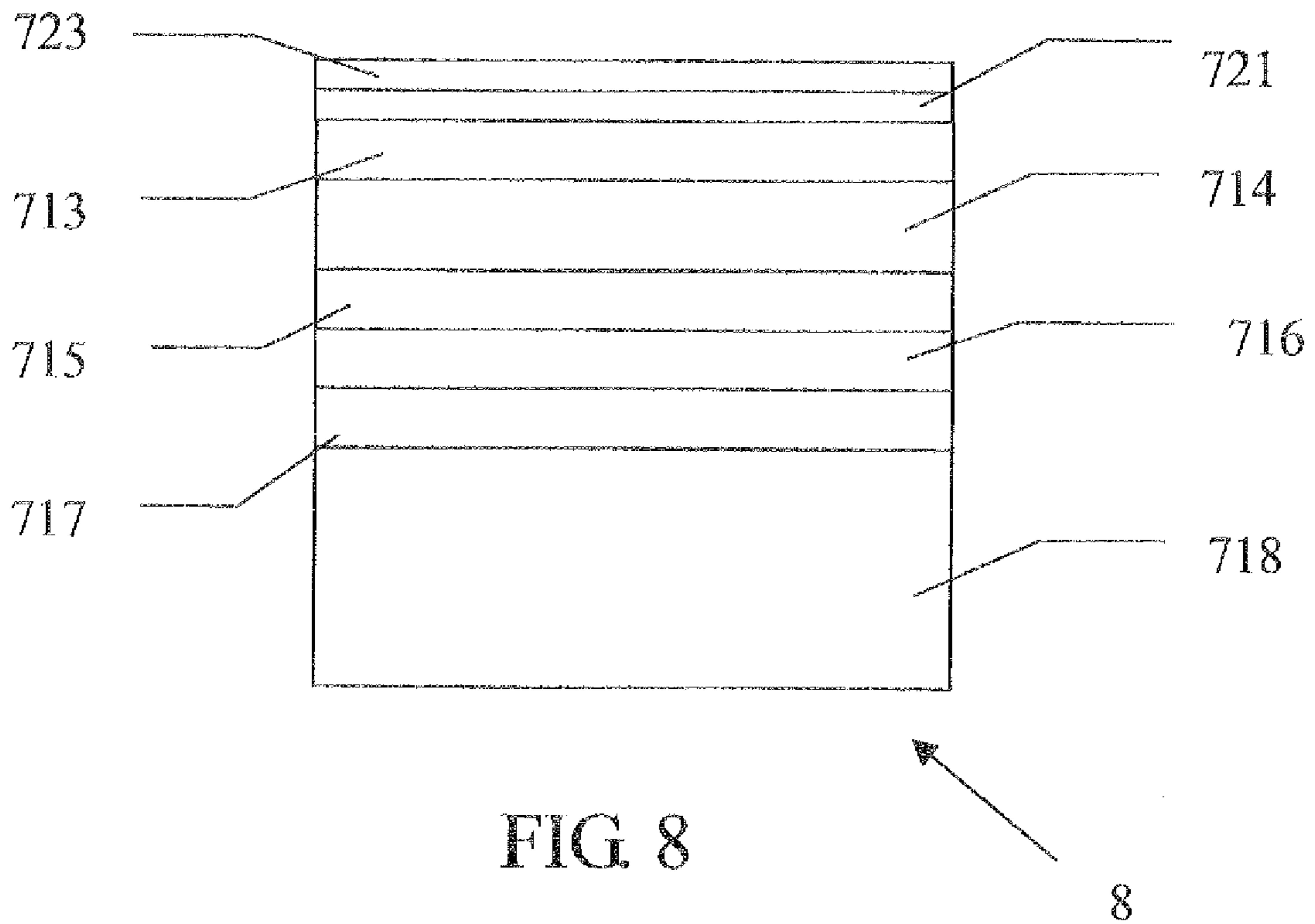
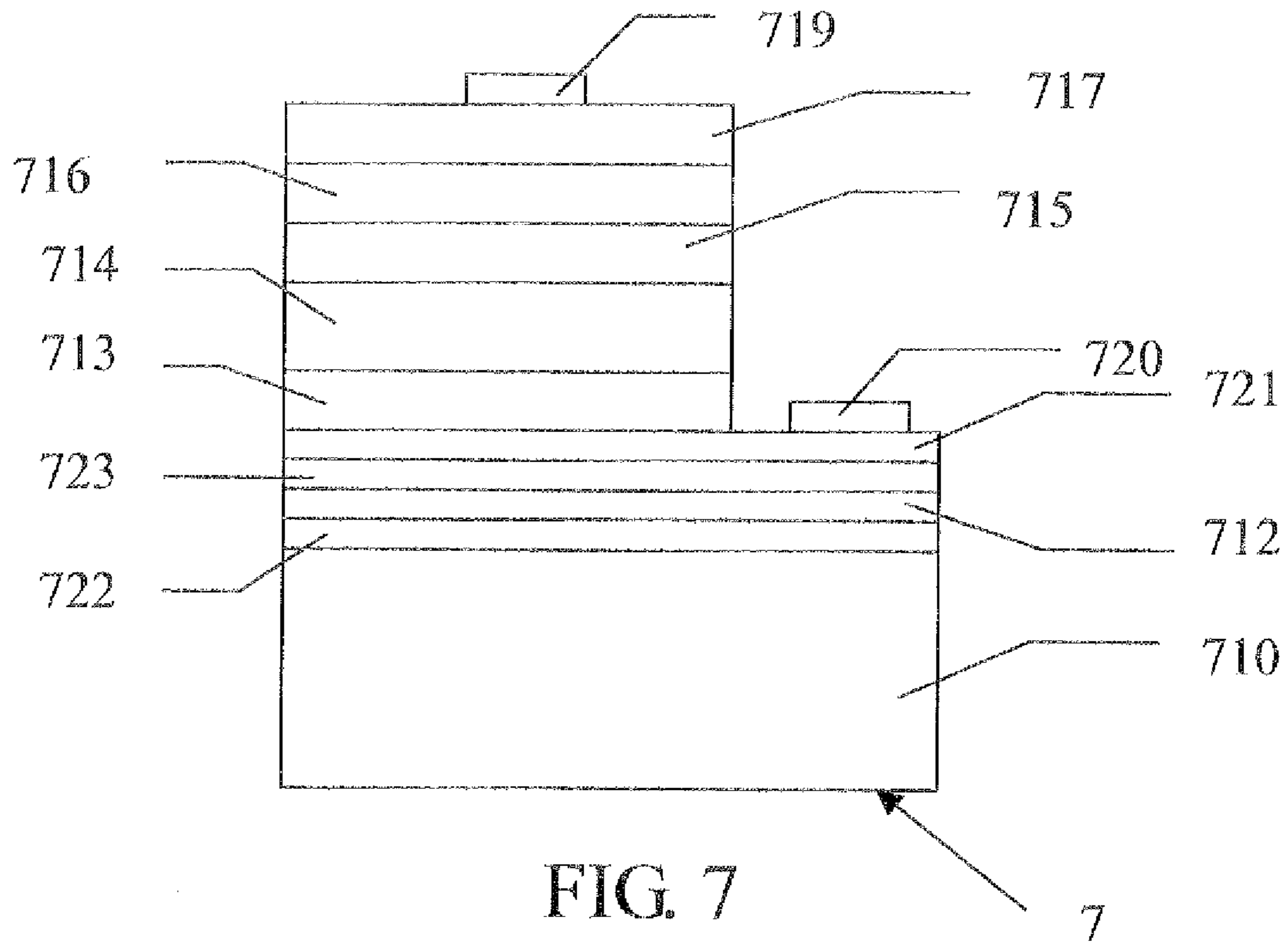


FIG. 6



6



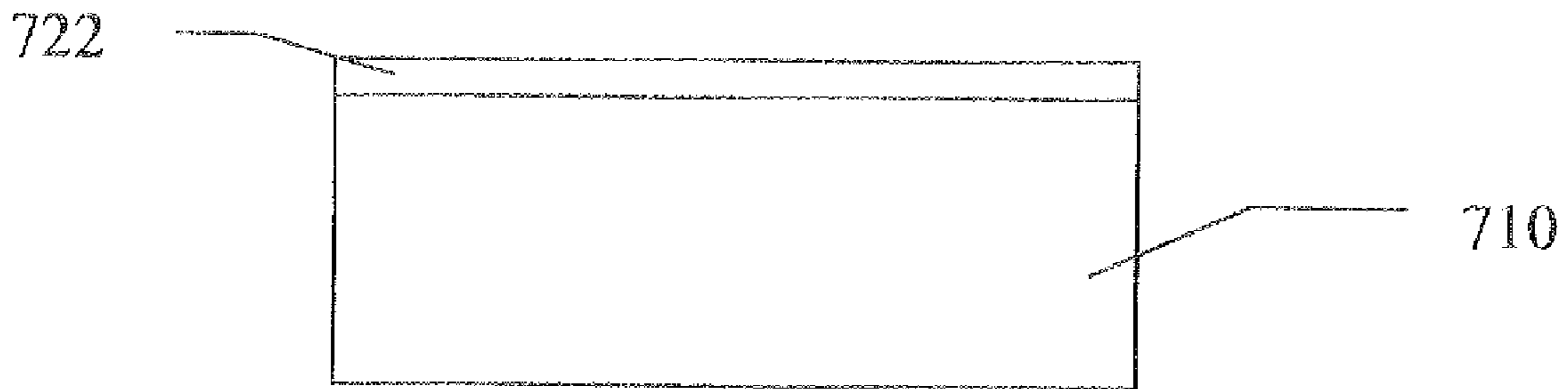


FIG. 9

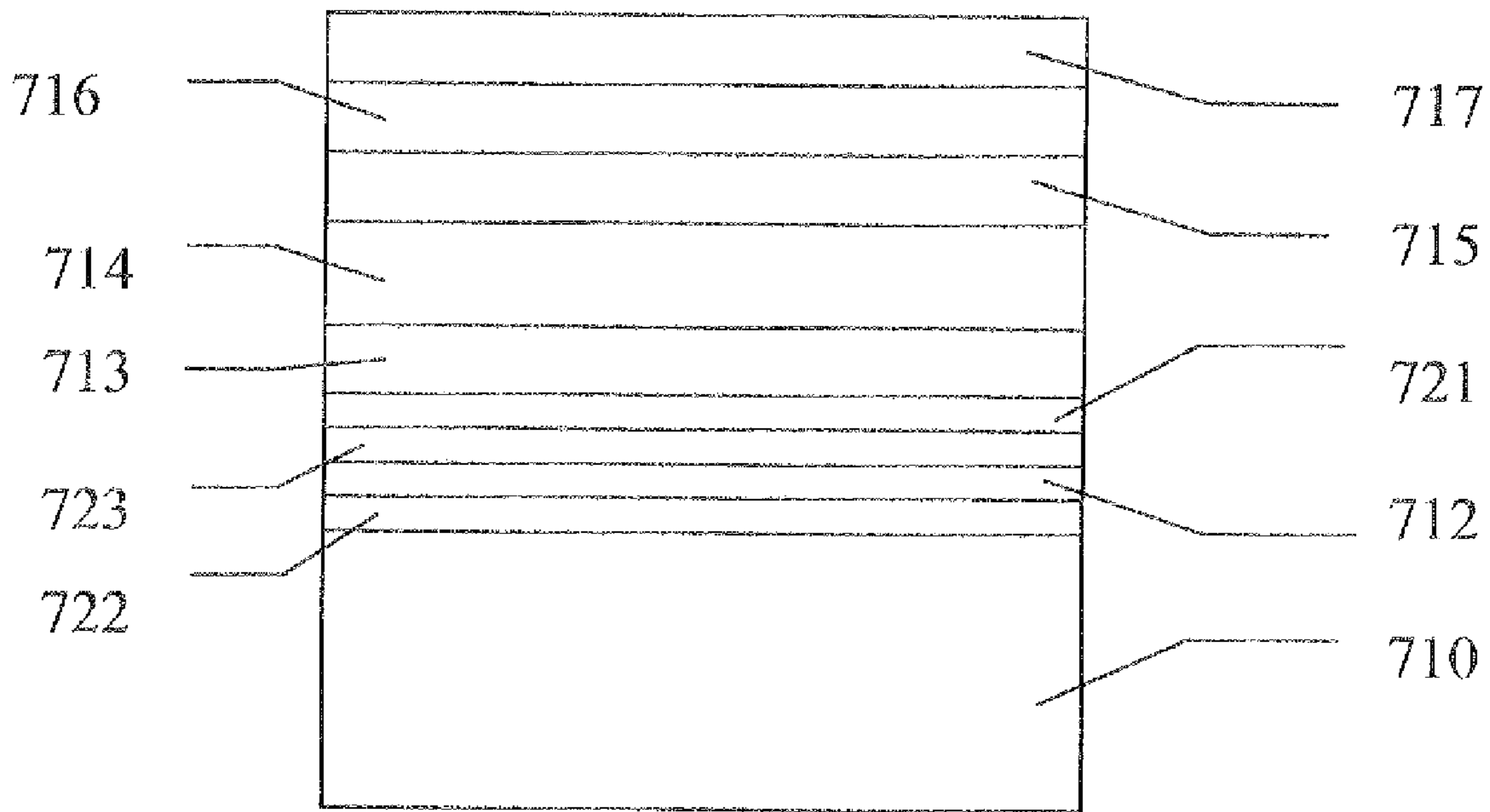
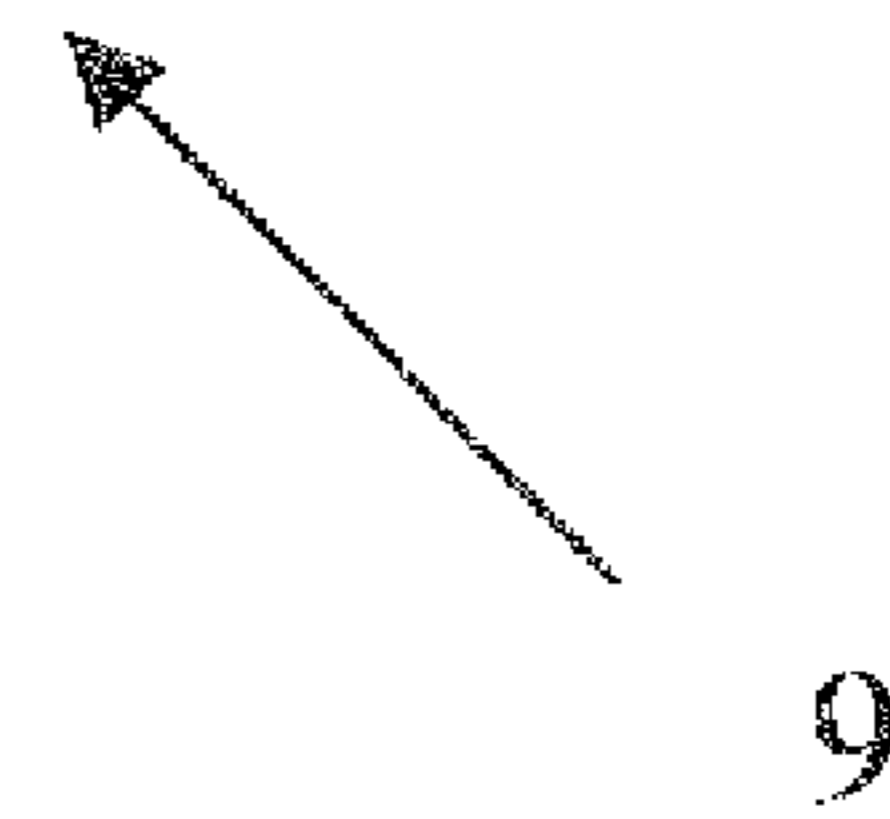
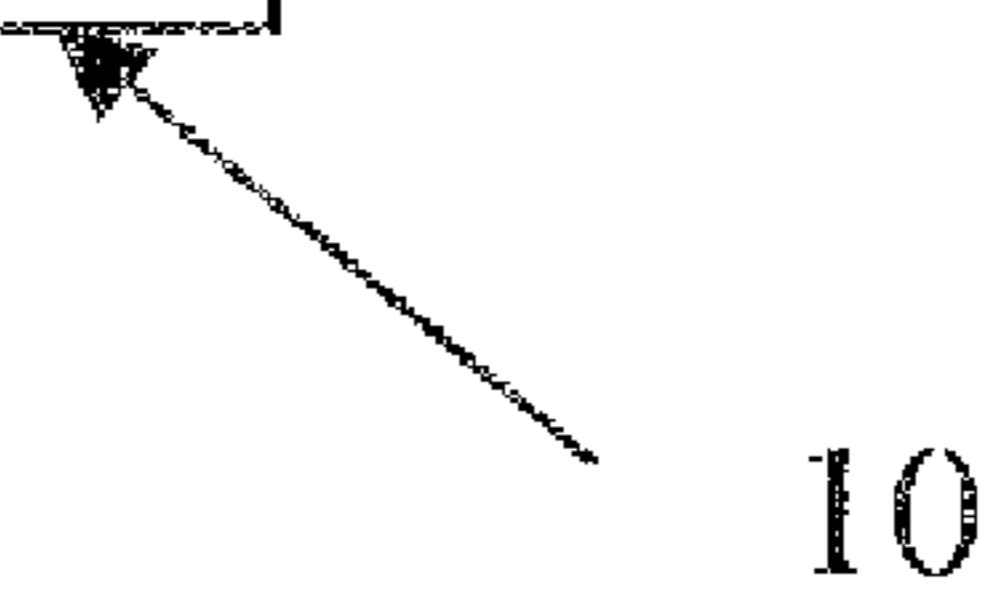


FIG. 10



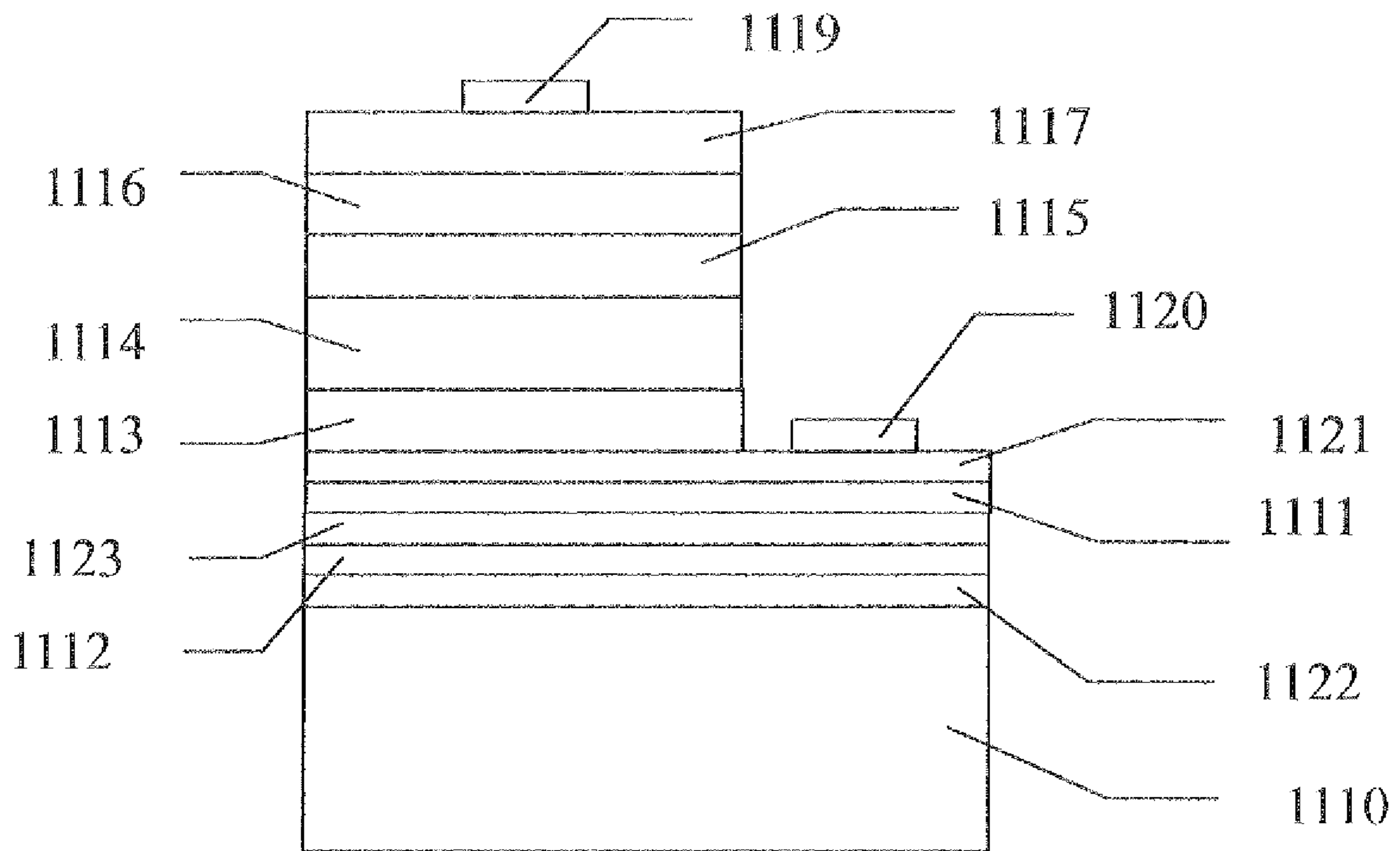


FIG. 11

110

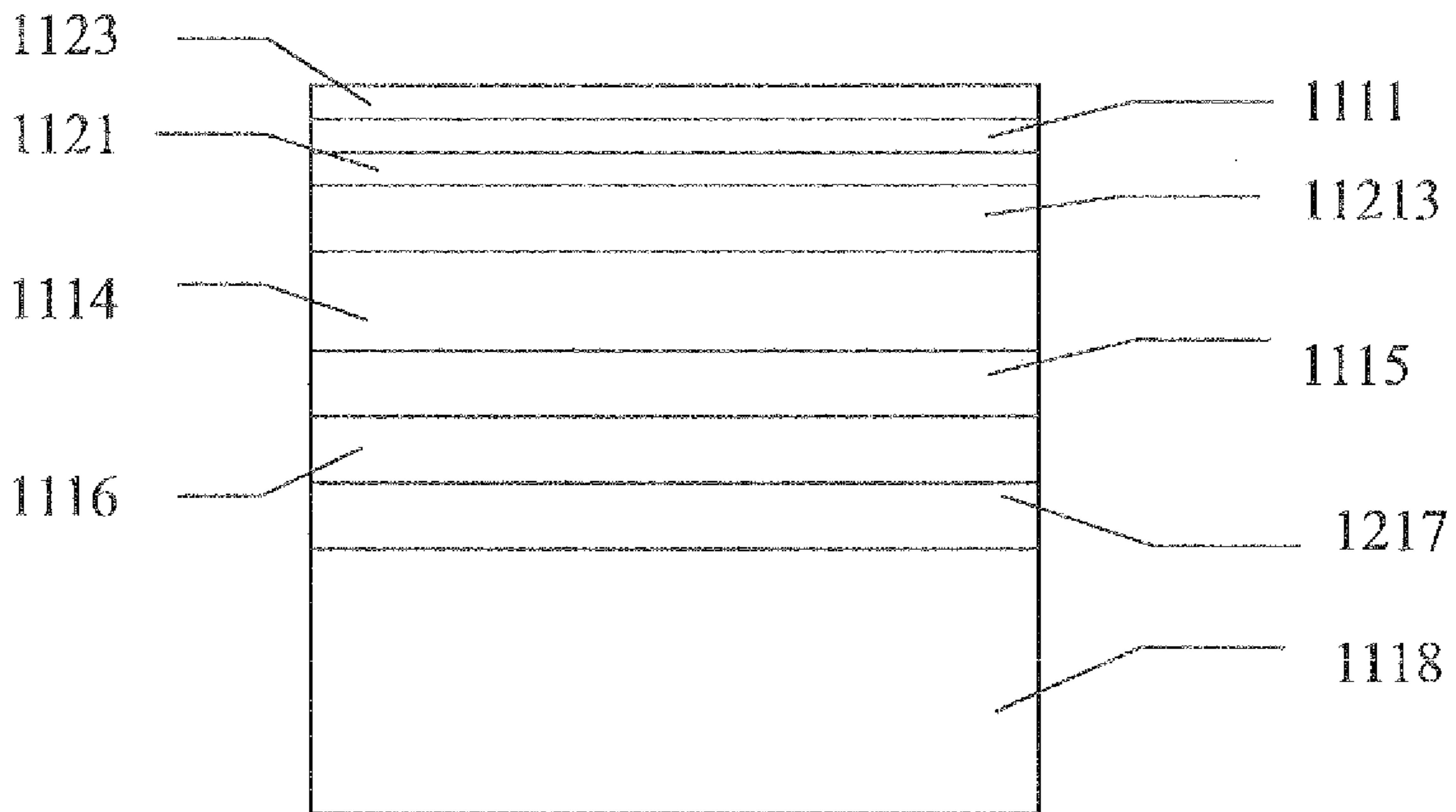


FIG. 12

120

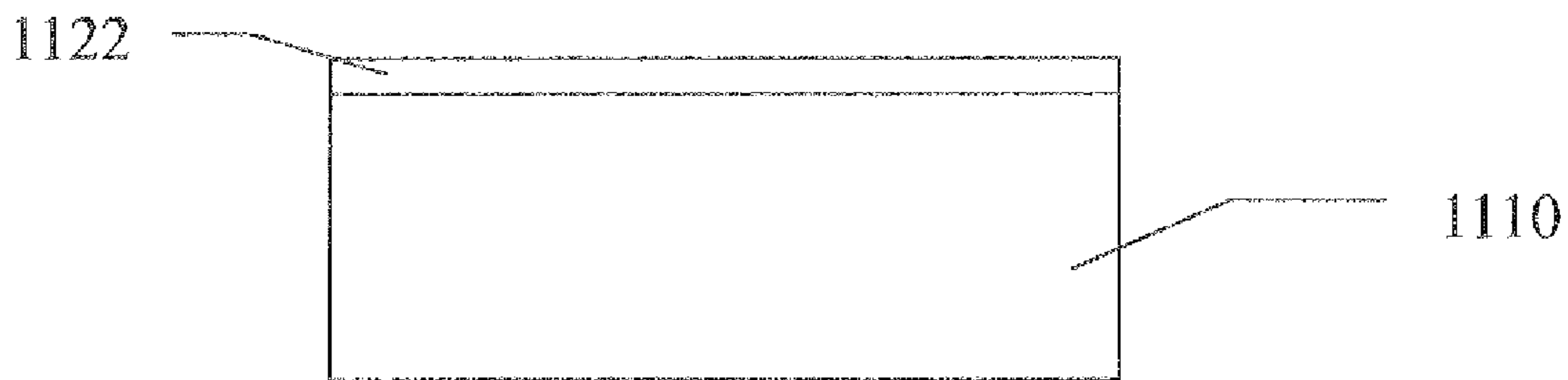


FIG. 13

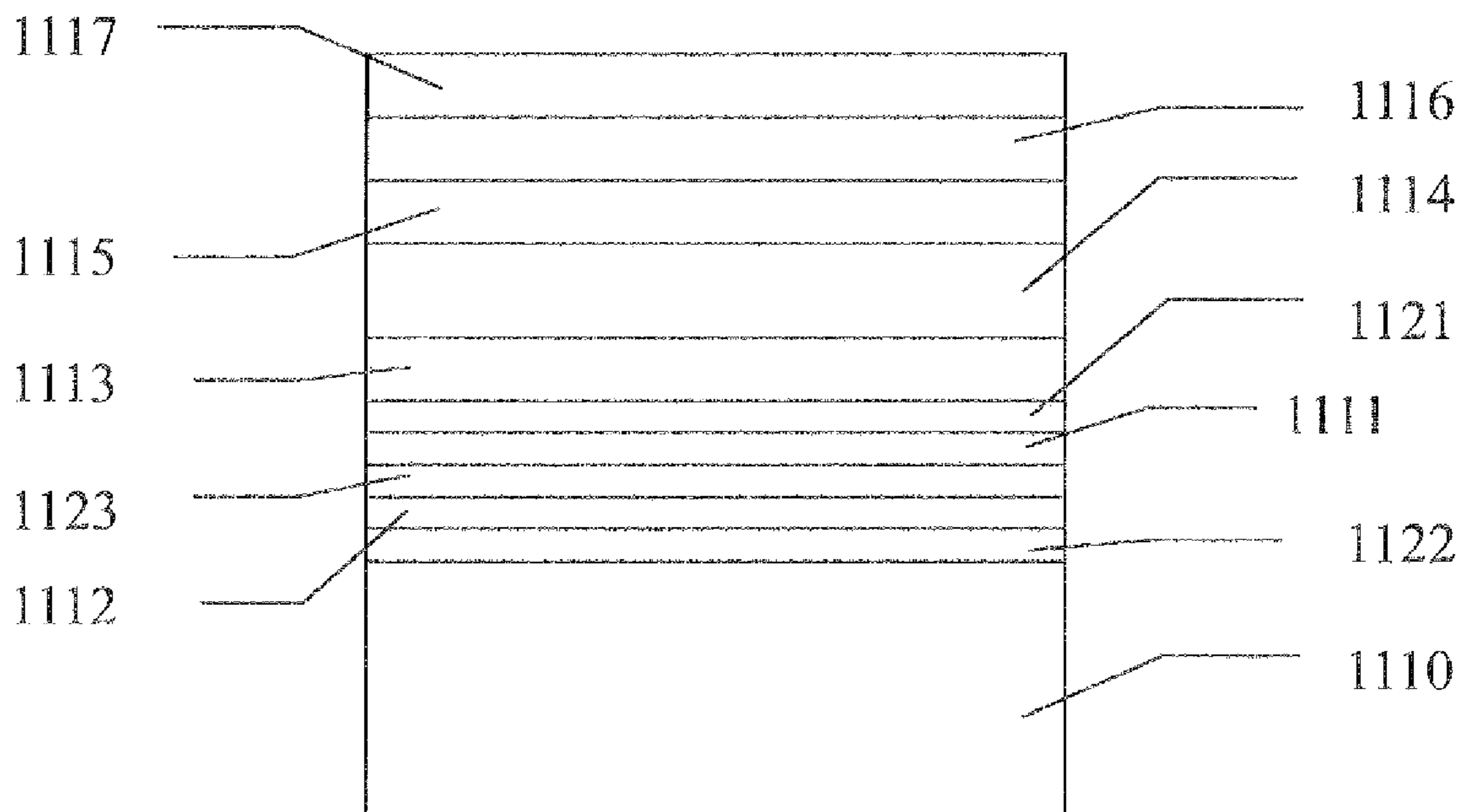
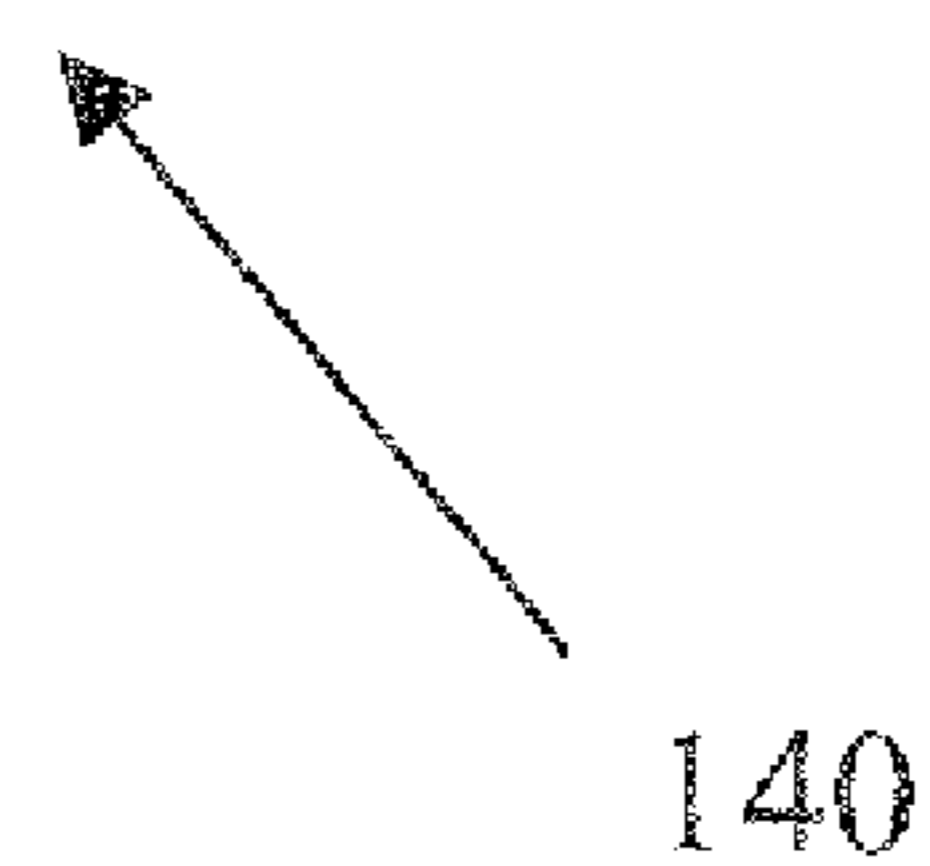


FIG. 14



1

**LIGHT EMITTING DIODE HAVING AN
ADHESIVE LAYER AND A REFLECTIVE
LAYER AND MANUFACTURING METHOD
THEREOF**

**CROSS REFERENCE TO RELATED
APPLICATIONS**

This application is a division of U.S. application Ser. No. 10/604,245 filed Jul. 4, 2003.

BACKGROUND OF INVENTION

1. Field of the Invention

The present invention relates to a light emitting diode and the manufacturing method thereof. More particularly, the invention is directed to a light emitting diode having an adhesive layer and a reflective layer and the manufacturing method thereof.

2. Description of the Prior Art

Light emitting diodes can be used in a wide variety of devices, for example, optical displays, traffic lights, data storage devices, communication devices, illumination devices, and medical devices. To manufacture a light emitting diode of higher brightness is an important task of engineers.

A prior art method for improving LED brightness involves bonding two semiconductor parts together by van der Waals forces. However, it has a disadvantage in that van der Waals forces are too weak to provide a sufficient mechanical bonding strength between the two parts and therefore they are apt to separate.

In U.S. Pat. No. 5,376,580, a method for bonding an LED stack and a transparent substrate to create an ohmic interface therebetween is disclosed. The transparent substrate can be made of GaP. The light generated from the LED stack can pass through the LED stack as well as the transparent substrate. However, this prior art method has to be carried out at about 1000° C. by exerting a coaxial compressive force on the LED stack and the transparent substrate to form an ohmic interface therebetween. The primary disadvantage of this prior art method lies in that the property of the LED is destroyed by the high temperature during the manufacturing process and this results in an LED of low light emitting efficiency. In addition, the transparent GaP substrate has a color and a transparency of only about 60–70%. It therefore reduces brightness of the LED.

Another prior art method for improving LED brightness involves a bonding technique using a metal layer to bond an LED stack and a substrate. The metal layer forms a bonding layer and a mirror through its metallic property. Thereby, the light rays emitted from the LED stack can be reflected at the metal layer and re-enter the LED stack without passing through the metal layer and entering the substrate. The disadvantage that the some light rays are absorbed by a substrate can therefore be avoided. In such a manufacturing process, the bonding temperature of the metal layer is only about 300–450° C. The LED property will not be destroyed at these low temperatures. However, this bonding technique involves a few disadvantages. One of the disadvantages lies in that although a low bonding temperature will not cause any reaction between the metal layer and any of the two semiconductor layers to be bonded and therefore a highly reflective metal surface (reflectivity over 90%) and improved light emitting efficiency can be obtained, the bonding effect is not sufficient due to that there is no reaction between the metal layer and any of the semiconductor layers

2

to be bonded, and an ohmic interface cannot be formed between the metal layer and any of the semiconductor layers to be bonded. Nevertheless, in case that a higher bonding temperature is adopted, the bonding between the metal layer and any of the two semiconductor layers to be bonded is good. However, the reflectivity of the reflective metal layer will be greatly reduced and therefore the metal layer cannot provide a good mirror function. This is another disadvantage of the bonding technique.

To avoid the aforementioned disadvantages, the inventors of the present application got an inventive concept to be explained in the following. In case a transparent adhesive layer is used for adhering a metal layer, as mentioned above, to an LED stack, light rays generated by the LED stack may pass through the transparent adhesive layer, be reflected by the metal layer, and then pass through the LED stack. However, if the metal layer is simply adhered to the LED stack by use of an adhesive layer, the adhesion between them is achieved only by van der Waals forces and peeling is apt to occur at the adhesion interface. The inventive concept lies in that a reaction layer is formed between the transparent adhesive layer and any of the LED stack and the metal layer, wherein a reaction occurs between the reaction layer and the transparent adhesive layer so that hydrogen bonds or ionic bonds are formed to enhance the bonding forces provided by the transparent adhesive layer. Thereby, the transparent adhesive layer can provide an enhanced mechanical strength and thus the above-mentioned disadvantage of peeling can be avoided. In addition, using the transparent adhesive layer can avoid the above-mentioned disadvantage caused by the bonding between the metal layer and the LED stack. Moreover, a transparent conductive layer can be formed between the transparent adhesive layer and the LED stack for improving the efficiency of current spreading and thereby can enhance the brightness of the LED.

SUMMARY OF INVENTION

An object of the invention is to provide a light emitting diode having an adhesive layer and a reflective layer and the manufacturing method thereof. In the manufacturing method, a transparent adhesive layer is used to bond an LED stack and a substrate having a reflective layer so that light can pass through the transparent adhesive layer and reflected at the reflective layer. On each of the upper and lower surfaces of the transparent adhesive layer is formed a reaction layer. The reaction layer creates reaction when it and the transparent adhesive layer is pressurized and heated to enhance the bonding forces at the adhesive surface for improving mechanical strength. The light directed to the reflective layer is reflected out to increase the brightness of the light emitting diode. Additionally, the reflective layer can also be formed between the LED stack and the reaction layer so that the adhesive layer does not have to be limited to a transparent adhesive layer and light directed to the reflective layer can be reflected out even a non-transparent adhesive layer is used. This method does not have any problems relating the decrease in reflectivity and decrease in bonding effect. Thereby, an effect of total reflection can be obtained and the object of increasing the brightness of an LED can be achieved.

A light emitting diode having an adhesive layer and a reflective layer in accordance with a preferred embodiment of the invention comprises a second substrate, a reflective metal layer formed on the second substrate, a first reaction layer formed on the reflective metal layer, a transparent adhesive layer formed on the first reaction layer, a second

3

reaction layer formed on the transparent adhesive layer, a transparent conductive layer formed on the second reaction layer, wherein the upper surface of the transparent conductive layer consists of a first surface area and a second surface area. A first contact layer is formed on the first surface area. A first cladding layer is formed on the first contact layer. An active layer is formed on the first cladding layer. A second cladding layer is formed on the active layer. A second contact layer is formed on the second cladding layer. A first electrode is formed on the second contact layer. A second electrode is formed on the second surface area.

The manufacturing method of a light emitting diode in accordance with a preferred embodiment of the invention comprises the following steps: forming in sequence, on a first substrate, a second contact layer, a second cladding layer, an active layer, a first cladding layer, a first contact layer, a transparent conductive layer, a second reaction layer to constitute a first stack; forming a reflective metal layer on a second substrate and forming a first reaction layer on the reflective metal layer to constitute a second stack; providing a transparent adhesive layer and using the transparent adhesive layer to bind together the first stack and the second stack by adhering it to the surface of the second reaction layer and the surface of the first reaction layer to constitute a third stack; removing the first substrate to constitute a fourth stack; suitably etching the fourth stack to the transparent conductive layer to form an exposed surface area of the transparent conductive layer; and forming a first electrode on the second contact layer and a second electrode on the exposed surface area of the transparent conductive layer.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a schematic diagram showing a light emitting diode having an adhesive layer and a reflective layer in accordance with a preferred embodiment of the invention.

FIG. 2 is a schematic diagram showing a first stack for use in a method for manufacturing a light emitting diode having an adhesive layer and a reflective layer, as shown in FIG. 1, in accordance with the invention.

FIG. 3 is a schematic diagram showing a second stack for use in a method for manufacturing a light emitting diode having an adhesive layer and a reflective layer, as shown in FIG. 1, in accordance with the invention.

FIG. 4 is a schematic diagram showing a third stack formed, after adhesive binding the first stack and the second stack and before removing the first substrate, in a method for manufacturing a light emitting diode having an adhesive layer and a reflective layer, as shown in FIG. 1, in accordance with the invention.

FIG. 5 is a schematic diagram showing a fourth stack formed, after removing the first substrate, in a method for manufacturing a light emitting diode having an adhesive layer and a reflective layer, as shown in FIG. 1, in accordance with the invention.

FIG. 6 is a schematic diagram showing a light emitting diode having an adhesive layer and a reflective layer in accordance with another preferred embodiment of the invention.

FIG. 7 is a schematic diagram showing a light emitting diode having an adhesive layer and a reflective layer in accordance with yet another preferred embodiment of the invention.

FIG. 8 is a schematic diagram showing a fifth stack for use in a method for manufacturing a light emitting diode having an adhesive layer and a reflective layer, as shown in FIG. 7, in accordance with the invention.

4

FIG. 9 is a schematic diagram showing a sixth stack for use in a method for manufacturing a light emitting diode having an adhesive layer and a reflective layer, as shown in FIG. 7, in accordance with the invention.

FIG. 10 is a schematic diagram showing a seventh stack formed, after adhesive binding the first stack and the second stack and before removing the first substrate, in a method for manufacturing a light emitting diode having an adhesive layer and a reflective layer, as shown in FIG. 7, in accordance with the invention.

FIG. 11 is a schematic diagram showing a light emitting diode having an adhesive layer and a reflective layer in accordance with still yet another preferred embodiment of the invention.

FIG. 12 is a schematic diagram showing an eighth stack for use in a method for manufacturing a light emitting diode having an adhesive layer and a reflective layer, as shown in FIG. 11, in accordance with the invention.

FIG. 13 is a schematic diagram showing a ninth stack for use in a method for manufacturing a light emitting diode having an adhesive layer and a reflective layer, as shown in FIG. 11, in accordance with the invention.

FIG. 14 is a schematic diagram showing a tenth stack formed, after adhesive binding the first stack and the second stack and before removing the first substrate, in a method for manufacturing a light emitting diode having an adhesive layer and a reflective layer, as shown in FIG. 11, in accordance with the invention.

DETAILED DESCRIPTION

Referring to FIG. 1, a light emitting diode having an adhesive layer and a reflective layer 1 in accordance with a preferred embodiment of the invention comprises a second substrate 10, a reflective metal layer 11 formed on the second substrate 10, a first reaction layer 22 formed on the reflective metal layer 11, a transparent adhesive layer 12 formed on the first reaction layer 22, a second reaction layer 23 formed on the transparent adhesive layer 12, a transparent conductive layer 21 formed on the second reaction layer 23, wherein the upper surface of the transparent conductive layer 21 consists of a first surface area and a second surface area. A first contact layer 13 is formed on the first surface area. A first cladding layer 14 is formed on the first contact layer 13. An active layer 15 is formed on the first cladding layer 14. A second cladding layer 16 is formed on the active layer 15. A second contact layer 17 is formed on the second cladding layer 16. A first electrode 19 is formed on the second contact layer 17. A second electrode 20 is formed on the second surface area.

Referring to FIGS. 1 to 5, the manufacturing method of the light emitting diode 1 comprises the following steps: forming in sequence, on a first substrate 18, a second contact layer 17, a second cladding layer 16, an active layer 15, a first cladding layer 14, a first contact layer 13, a transparent conductive layer 21, a second reaction layer 23 to constitute a first stack 2; forming a reflective metal layer 11 on a second substrate 10 and forming a first reaction layer 22 on the reflective metal layer 11 to constitute a second stack 3, as shown in FIG. 3; providing a transparent adhesive layer 12 and using the transparent adhesive layer 12 to bind together the first stack 2 and the second stack 3 by adhering it to the surface of the second reaction layer 23 and the surface of the first reaction layer 22 to constitute a third stack 4, as shown in FIG. 4; removing the first substrate 18 to constitute a fourth stack 5, as shown in FIG. 5; suitably etching the fourth stack 5 to the transparent conductive layer 21 to form

5

an exposed surface area of the transparent conductive layer **21**; and forming a first electrode **19** on the second contact layer **17** and a second electrode **20** on the exposed surface area of the transparent conductive layer **21**.

A light emitting diode having an adhesive layer and a reflective layer **6** in accordance with another preferred embodiment of the invention is shown in FIG. **6**. The LED structure and manufacturing method of this LED **6** is similar to that in accordance with the aforementioned preferred embodiment except that the reflective metal layer **11** is replaced by a reflective oxide layer **611** by which the light directed to the reflective oxide layer **611** can be reflected and taken out.

Referring to FIG. **7**, a light emitting diode having an adhesive layer and a reflective layer **7** in accordance with yet another preferred embodiment of the invention comprises a reflective metal substrate **710**; a first reaction layer **722** formed on the reflective metal substrate **710**; a transparent adhesive layer **712** formed on the first reaction layer **722**; a second reaction layer **723** formed on the transparent adhesive layer **712**; a transparent conductive layer **721** formed on the second reaction layer **723**; wherein the transparent conductive layer **721** comprises a first surface area and a second surface area; a first contact layer **713** formed on the first surface area; a first cladding layer **714** formed on the first contact layer **713**; an active layer **715** formed on the first cladding layer **714**; a second cladding layer **716** formed on the active layer **715**; a second contact layer **717** formed on the second cladding layer **716**; a first electrode **719** formed on the second contact layer **717**; and the second electrode **720** formed on the second surface area.

Referring to FIGS. **7** to **10**, the manufacturing method of the LED **7** comprises the following steps: forming in sequence, on a first substrate **718**, a second contact layer **717**, a second cladding layer **716**, an active layer **715**, a first cladding layer **714**, a first contact layer **713**, a transparent conductive layer **721**, a second reaction layer **723** to constitute a fifth stack **8**; forming a first reaction layer **722** on a reflective metal substrate **710** to constitute a sixth stack **9**; bonding the surface of the second reaction layer of the first stack with the surface of the first reaction layer of the sixth stack by use of a transparent adhesive layer **712**; removing the first substrate **718** to leave a seventh stack **100**; suitably etching the seventh stack **100** to form an exposed surface area of the transparent conductive layer **721**; and forming a first electrode **719** and a second electrode **720** respectively on the second contact layer **717** and the exposed surface area of the transparent conductive layer **721**.

Referring to FIG. **11**, a light emitting diode **110** in accordance with another preferred embodiment of the invention comprises a second substrate **1110**; a first reaction layer **1122** formed on the second substrate **1110**; an adhesive layer **1112** formed on the first reaction layer **1122**; a second reaction layer **1123** formed on the adhesive layer **1112**; a reflective metal layer **1111** formed on the second reaction layer **1123**; a transparent conductive layer **1121** formed on the reflective metal layer **1111**, wherein the transparent conductive layer **1121** comprises a first surface area and a second surface area; a first contact layer **1113** formed on the first surface area; a first cladding layer **1114** formed on the first contact layer **1113**; an active layer **1115** formed on the first cladding layer **1114**; a second cladding layer **1116** formed on the active layer **1115**; a second contact layer **1117** formed on the second cladding layer **1116**; a first electrode **1119** formed on the second contact layer **1117**; and a second electrode **1120** formed on the second surface area.

6

Referring to FIGS. **12** to **14**, a method for manufacturing the light emitting diode **110** comprises the following steps: forming, in sequence, on a first substrate **1118**, a second contact layer **1117**, a second cladding layer **1116**, an active layer **1115**, a first cladding layer **1114**, a first contact layer **1113**, a transparent conductive layer **1121**, a reflective metal layer **1111**, a second reaction layer **1123** to constitute an eighth stack **120**; forming a first reaction layer **1122** on a second substrate **1110** to constitute a ninth stack **130**; bonding together the surface of the second reaction layer **1123** of the eighth stack **120** and the surface of the first reaction layer **1122** of the ninth stack **130** by use of an adhesive layer **1112**; removing the first substrate **1118** to constitute a tenth stack **140**; suitably etching the tenth stack **140** to the transparent conductive layer **1121** to form an exposed surface area of the first contact layer **1113**; and forming a first electrode **1119** and a second electrode **1120** respectively on the second contact layer **1117** and the exposed surface area of the first contact layer **1113**.

The first substrate **18**, **718**, or **1118** comprises at least a material selected from the group consisting of GaP, GaAs, and Ge. The second substrate **10** or **1110** comprises at least a material selected from the group consisting of Si, GaAs, SiC, Al₂O₃, glass, GaP, GaAsP, and AlGaAs. The transparent adhesive layer **12** or **1112** comprises at least a material selected from the group consisting of polyimide (PI), benzocyclobutene (BCB), perfluorocyclobutane (PFCB), and the like. The first reaction layer **22**, **722**, or **1122** comprises at least a material selected from the group consisting of SiN_x, Ti, and Cr. The second reaction layer **23**, **723**, or **1123** comprises at least a material selected from the group consisting of SiN_x, Ti, and Cr, and the like. The reflective metal substrate **710** comprises at least a material selected from the group consisting of Sn, Al, Au, Pt, Zn, Ag, Ti, Pb, Pd, Ge, Cu, AuBe, AuGe, Ni, PbSn, AuZn, and the like. The first contact layer **13**, **713**, or **1113** comprises at least a material selected from the group consisting of GaP, GaAs, GaAsP, InGaP, AlGaInP, and AlGaAs. The reflective oxide layer **611** comprises at least a material selected from the group consisting of SiN_x, SiO₂, Al₂O₃, TiO₂, MgO, and the like. The reflective metal layer **11** or **1111** comprises at least a material selected from the group consisting of In, Sn, Al, Au, Pt, Zn, Ag, Ti, Pb, Pd, Ge, Cu, AuBe, AuGe, Ni, PbSn, AuZn, and the like. Each of the first cladding layer **14**, **714**, or **1114**, the active layer **15**, **715**, or **1115**, and the second cladding layer **16**, **716**, or **1116** comprises AlGaInP. The second contact layer **17**, **717**, **1117** comprises at least a material selected from the group consisting of GaP, GaAs, GaAsP, InGaP, AlGaInP, and AlGaAs. The transparent conductive layer **21**, **721**, or **1121** comprises at least a material selected from the group consisting of indium tin oxide, cadmium tin oxide, antimony tin oxide, zinc oxide, and zinc tin oxide.

Although the preferred embodiments of the invention has been illustrated and described in the above, it will be obvious to those skilled in the art that various modifications may be made without departing from the scope and spirit of the invention defined by the appended claims.

What is claimed is:

1. A method for manufacturing a light emitting diode comprising the steps of:
 - forming an LED stack over a first substrate;
 - forming a reflective layer over said LED stack;
 - forming a first reaction layer over said reflective layer;
 - forming a second reaction layer over a second substrate;
 - and
 - holding together said first reaction layer and said second reaction layer by means of an adhesive layer,

7

wherein each of the first and second reaction layers comprises at least a material selected from the group consisting of SiN_x , Ti, and Cr, and is formed to enhance an adhesion provided by the adhesive layer; and

wherein said adhesive layer comprises a material selected from the group consisting of polyimide (PI), benzocyclobutene (BCB), and perfluorocyclobutane (PFCB).

2. A method for manufacturing a light emitting diode according to claim 1, wherein said reflective layer is a reflective metal layer.

3. A method for manufacturing a light emitting diode according to claim 1, wherein said reflective layer is a reflective oxide layer.

8

4. A method for manufacturing a light emitting diode according to claim 2, wherein said reflective metal layer comprises a material selected from the group consisting of In, Sn, Al, Au, Pt, Zn, Ag, Ti, Pb, Pd, Ge, Cu, AuBe, AuGe, Ni, PbSn, and AuZn.

5. A method for manufacturing a light emitting diode according to claim 3, wherein said reflective oxide layer comprises a material selected from the group consisting of SiN_x , SiO_2 , Al_2O_3 , TiO_2 , and MgO.

6. A method for manufacturing a light emitting diode according to claim 1 wherein the method further comprises the step of removing said first substrate.

* * * * *